Geological and Geomorphological Hazard in Historical and Archaeological Sites of the Mediterranean Area: Knowledge, Forecasting and Mitigation

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Abstract

This study explains the results of a research programme concerning geological and geomorphological hazards caused by earthquakes and landslides involving important archaeological and historical sites of the Mediterranean area. Several historical and monumental sites have been taken into account, such as Petra, Dougga, Delphi and some centres in Montenegro. Many researches have proved that a close relation exists between earthquakes and landslides locally caused by medium-high magnitude events. Actually, those events influenced the survival of entire communities and the preservation of their historical and monumental testimonies. Even anthropic intervention has sometimes contributed to the deterioration of monuments and to the disappearance of important historical testimonies.

Each of these sites have been analysed according to their geomorphological features and to the dynamic response of the territory, pointing out prevention and static renewal measures useful to preserve the important heritage of the Mediterranean area, partially protected and included in the UNESCO's World Heritage.

Keywords: Geomorphological hazard, cultural heritage, Mediterranean basin, monitoring techniques, landslide, earthquake, UNESCO.

Introduction

This study contains a series of research started within the National Defence Group for Hydrogeological Catastrophes of the Italian National Researches Council (GNDCI-CNR). The group is no longer in service even if all the researches have continued and are still in progress. The objective of the programme's first phase aims at analysing the phenomenology in action, assessing the effects and detecting possible intervention to reduce the damages in the Mediterranean area due to frequent geological events, such as landslides, floods and earthquakes that affect remarkable archaeological and historical sites.

This study has been carried out by using traditional research methods (geological and geomorphologic field survey, multitemporal aerial photo interpretation, lab analysis, cartographic processing) supported by advanced systems for monitoring the territory and processing environmental data and remote sensed images (Environmental Monitoring System, called "SIMONA"). One of the most interesting thematic is the relationship between earthquakes and landslides from the point of view of the mechanisms and the trigger thresholds as well as the effects on the soil.

Moreover, it is common knowledge that climatic conditions, geological, geomorphological, hydrogeological and geotechnical conditions the spatial and temporal landslides earthquake-triggered can increase the damage level. Consequently, the study of both phenomena is a relevant means of prevention. This is very important for those archaeological sites and historical centres that are situated in seismic zones and that are affected by cyclic stresses that often interact on slopes, undermining stability.

In the Mediterranean area, there are a lot of examples, some of which are inserted in the UNESCO's list of protect sites, where the above mentioned conditions have been determined and studied. A close examination of these case studies could also lead to a reinterpretation of those historical events that caused the decline of single settlements or entire communities in the past.

The studied sites and technology

The programme has required analysis and control supported by data processing systems and ultimate generation technology of space mapping. More than 20 sites have been studied in all (Fig. 1) from north to south: Lorca (Spain), some coastal centres in Montenegro (Cattaro, Budva, Bar and Ulcinj), Delphi and Parga (Greece), Butrint (Albania), Epheso and Cappadocia rocky settlements (Turky), Petra (Jordan), Dougga (Tunisia), as well as some Italian centres that have been damaged by various seismic and hydro geological calamities.

Many sites are registered on UNESCO's World Heritage list and are affected by serious deterioration and hazard phenomena kept under control not only by the single nations but also by an appropriate World Heritage Committee that every six years draws up some periodical reports about their preservation, protection and management status[21]. Among all the surveyed sites in this paper we will focus on Dougga, Petra, Delphi sites and the coastal settlements in Montenegro. The analysis of those places lying on the Mediterranean premises has allowed to obtain an integrated synoptic table of centres raised up by different conditions of geological and seismic hazard often damaged by highly destructive events but of great cultural interest due to their past.

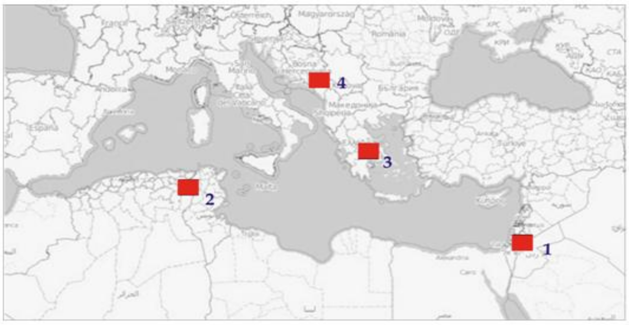

Figure 1: Geographic location of the studied sites. Legend: 1) Petra; 2) Dougga; 3) Delfi; 4) Montenegro coastal centers

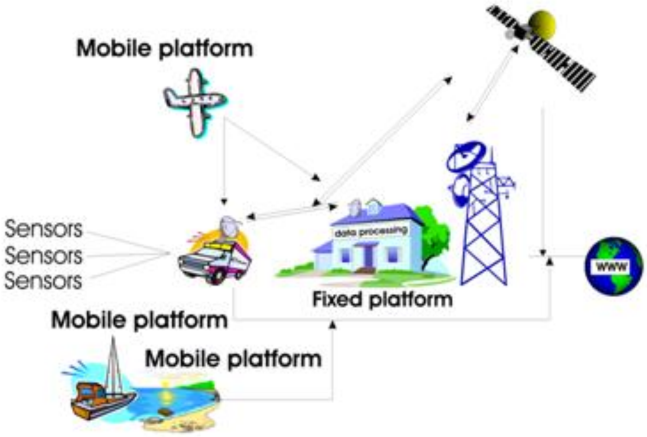

Figure 2: Main components of SIMONA structure

The researches have been carried out through field-survey mapping methods first, then through more incisive and modern ones as algorithms, remote sensed images and the web. These modern techniques are implemented in the system called SIMONA[17] (SIstema di MONitoraggio Ambientale - Environmental Monitoring System), a modular system based on space and terrestrial platforms equipped with sensors and integrated with ICT technologies that use web-sensors and web-services as means of data entry and processing with possible real time applications.

The system offers several applications in the environmental monitoring field. Moreover it allows analysis not only of the environmental component but also emergency configuration, even hydro geological during the whole process providing a proper control activity of the territory in relation to the risks related to climatic changes in action.

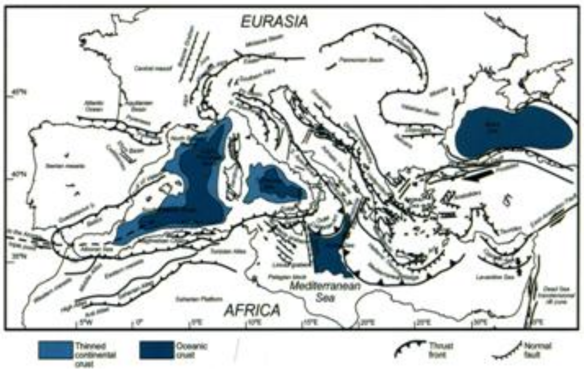

Figure 3 - Tectonic sketch of the Mediterranean region[26]

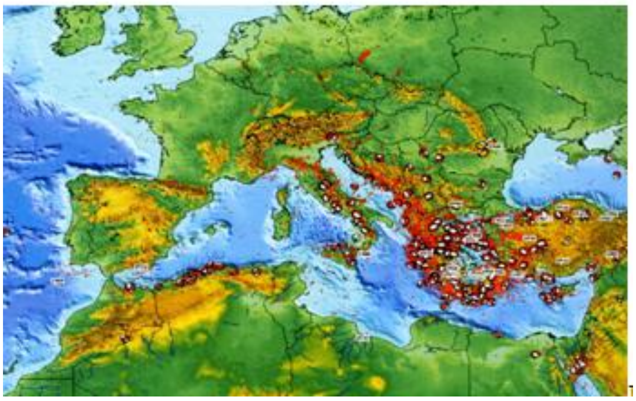

Figure 4: Seismicity in the Mediterranean area with epicentres of Ms>4 recorded from 1961 to 2004[1]

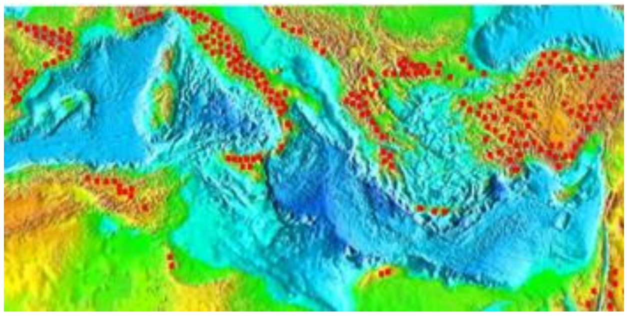

Figure 5: Map of the erosion and landslide risk

This system is composed of three independent but at the same time interoperable platforms: aerial mobile, supported by satellite images; terrestrial mobile and fixed. It allows the implementation of various sensors and data acquisition platforms via web, GSM-GPRS networks and satellite networks. When data are in the databases, they can be developed into numerical descriptive and cartographic form.

Figure 2 shows SIMONA's structure with all the possible spatial and terrestrial components that allow both data and images acquisition and their processing. Sensors are not fixed but vary according to specific parameters that can be geotechnical, hydraulic, hydro geological and physical-chemical.

Figure 6: Example of mudflow landslide in Aliano built-up area in Basilicata region activated by the earthquake on 23 November 1980

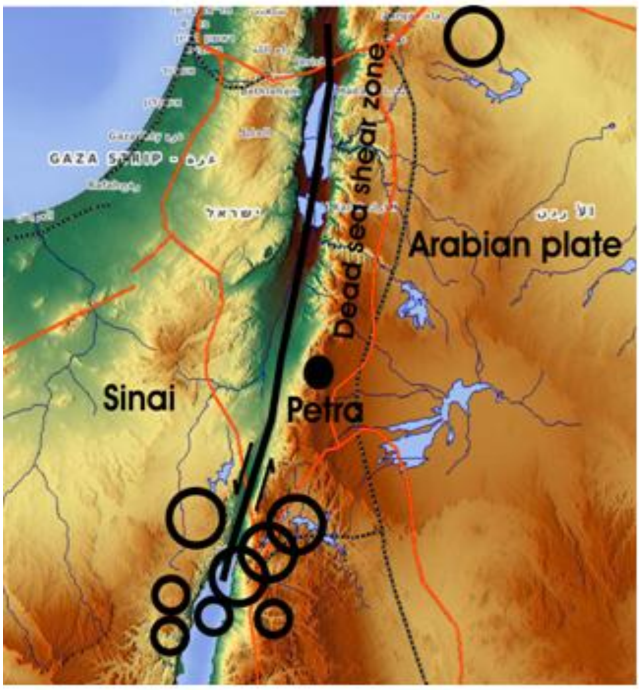

Figure 7: Localisation of Petra close to active tectonic of the Dead Sea line. The main earthquakes with epicentre in Aquaba Gulf are reported

Earthquakes and landslides in the Mediterranean area

Many experiences and research carried out by several authors as Sarma[25], Cotecchia[6], Ishihara et al[13], Crespellani et al[7], Dramis and Blumetti[9,10] and Porfidio et al[24] have proved the existence of a close relation between earthquakes and mass movements [2,8,18,20,27]. In fact, during or after the seismic phase, slopes can be damaged by effects that can be found not only in fractured rocky clusters but also in cohesive soils more or less saturated and in incoherent granular deposits.

Figure 8: Erosion and rock falls at the Tomb of the Urn Complex in Petra

Over the centuries, a lot of events have produced soil-effects related to landslides triggering[19] such as the landslides occurred in Gemona (Italy) during the earthquake that affected Friuli region in 1976, or those triggered during and after the 23 November 1980 (Irpinian earthquake) in Campania and Basilicata regions in southern Italy (Muro Lucano, Calitri, Senerchia, Satriano, Bella towns) or during the earthquake occurred in Calabria in 1783.

Koukis[15] pointed out some rockfall phenomena occurred along the calcareous walls during the strong earthquake that affected the Corinthian Gulf in 1981. It activated the displacement of wide detrital deposits that covered entire sides of the following places: Pissia, Parachora, Alepochori and the road Athens-Corinth.

A territorial analysis concerning mass movements was carried out by Cotecchia[6] in which the author focuses on several examples of landslides caused by the earthquake occurred between Campania and Basilicata in 1980. Zecchi[28] proposed a chart of the Italian territory in which the soil-effects occurred between years “zero” to 1986 due to earthquake-triggered landslides have been mapped.

More recently Dramis and Blumetti[9] have highlighted how some structural elements belonging to the Mediterranean area as the active faults, produce earthquakes of different intensity thus acting as the main agents that influence the geomorphological setting of large areas. These faults activate new forms or rejuvenate pre-existent forms including seismic-gravity forms that can be identified as landslides, deep gravity deformations and sinkholes, as well as deformations, liquefactions and local compaction of the soil.

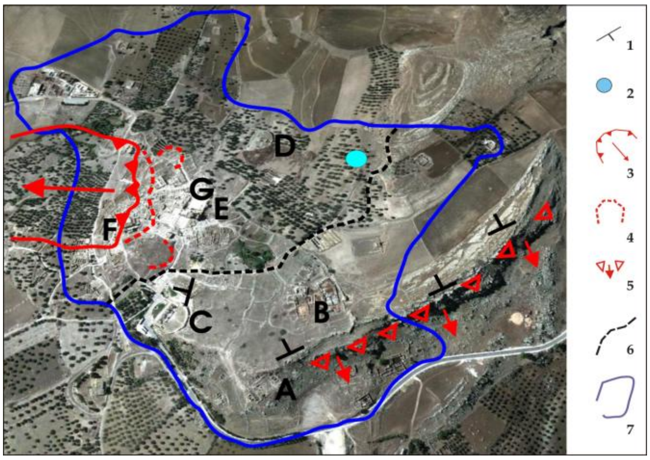

Figure 9: Spatial view and photo interpretation of Dougga: (A) Saturn's Temple; (B) Minerva's Temple; (C) Theatre; (D) Celeste's Temple; (E) Forum; (F) Trifolium's House; (G) Lucinians' Thermae, 1) layers dipping; 2) Spring; 3) planar slip and direction of the movement; 4) deformations and soil cracks; 5) collapses and movement direction; 6) limestone-clay stratigraphic limit; 7) archaeological area

Figure 10: Appearance of the unstable area with ancient retaining walls (Dougga). In the foreground the outcrop of plastic clays is seen

It is common knowledge that an earthquake produces in a slope some transitory stresses of cyclic type that can change direction increasing or reducing stability. Final effects of these stresses can be those of producing deformations and permanent displacements that can activate mass movements in particular geological, morphological, geotechnical and hydro geological conditions.

A significant increase of security coefficient can be obtained with the combination of the saturation of the soil and the effects of a medium-high magnitude earthquake. From a first analysis of seismic hazard and geological configuration a non-accidental coincidence emerges among perimediterranean zones where landslides and earthquakes are more frequent and intense. Earthquakes that occur in the Mediterranean area are connected with its particular position as regards to Euro-Asian and African plates in collision (Fig 3).

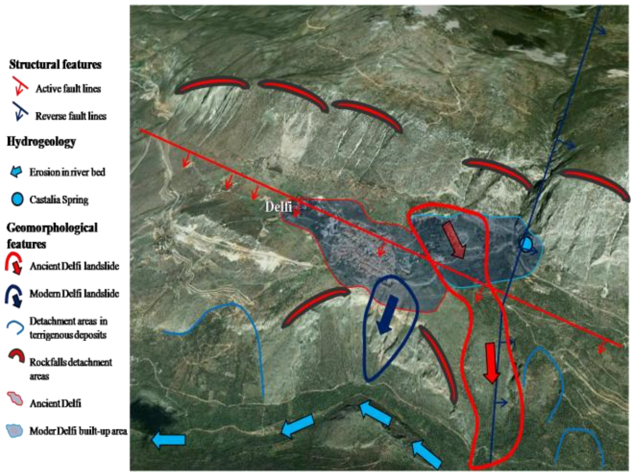

Figure 11: Aerial view and photo interpretation of Delphi site, dominated by unstable calcareous reliefs

The convergence of these plates has produced a complex system of continental blocks, separated by basins and mountain chains in evolution where stress fields of a distensive and compressive type that occur in different structural elements coincide with the territories where earthquakes are more frequent and intense, such as the Algerian Tell, middle-southern Apennines, south-Dinaric and Hellenic belts, Aegean arch and Anatolian chain. A quite moderate seismic activity characterises the northern Mediterranean areas[3] such as the Betica Cordillera, Pyrenees, Alpine system and the northern-Dinaric chain, although, even in these areas (Fig. 4), isolated seismic events of medium-high magnitude have occurred[1]. Such a context is characterized by very recent and less diagenic clastic deposits (upper Pliocene -Pleistocene), with high landslide susceptibility values, that filled the emerging basins of continental Euro-Asian and African borders (Fig. 5).

The slope dynamics is more active in case of particular geological-structural settings and during extreme rainfall events. Heavy rains in a short time, typical of a dry-temperate Mediterranean climate, erode and undermine slopes. The most disadvantageous structural-geological conditions mainly characterised by clay deposits are subjected to compressive and distensive tensions that have slightly modified the mass structure and consistency often affected by deformations and tectonic displacements[12]. In these environments, a wide range of gravitational events occur due to erosion and mass movements (Fig. 6).

Risk analysis of the study sites

Petra: The ancient settlement of Petra is located in southern Jordan and it is an archaeological site declared as a World Heritage site by UNESCO in 1985. In 2007, it was revealed to the world as one of the seven wonders of the modern world. It is situated 800-900 metres above sea level in the rocky region of Edon east of Wadi Araban near the active tectonic line that separates Sinai peninsula from Saudi Arabia, which is characterised by a frequent seismic activity presenting high magnitude events as those occurred in 363, 551 and 1130 AD and historically documented (Fig. 7).

Human traces date back to X-IX millennium BC. Petra, first populated by Edomites and then by Nabateans and inhabited until the late Middle Ages, preserves an extraordinary archaeological and monumental heritage reachable by a deep gorge cut into the rock which is called “Siq”. It allows us to enter a close passage whose walls are engraved with monumental buildings mostly used as tombs.

Figure 12: Overview of Delphi’s archaeological area with wide outcrops of debris and collapses occurred in fractured limestones

The whole site is built or caved within the Palaeozoic formation of Umm Ishrin Sandstone (Cambrian -Ordovician) characterized by sandstones with high quartz contents (80%-90%) and kaolinitic, hematite, goethite and calcite concrete. The sandstones are interested by a good compactness and structural discontinuities such as bedding joints and fractures of various sizes and geometries.

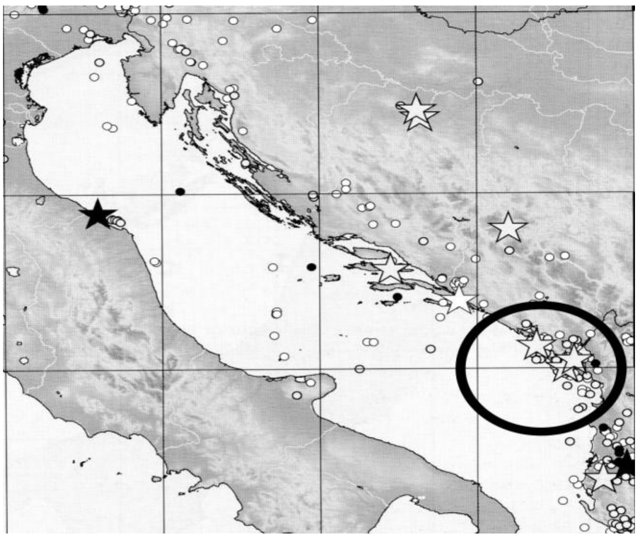

Figure 13: Distribution of the epicentres located near or within the coastal areas in Montenegro. Stars show earthquakes with Ms>6 (Peruzza et al[22] partially modified)

These characteristics tend to change thus facilitating the progressive rock deterioration due to temperature changes, wind erosion, heavy rains and runoff and the chemical deterioration of the calcitic concrete. Moreover, salts act on fractures and joints weakening and widening the joints both on the surface and into caves.

Despite the arid climate, characterized by an average annual rainfall ranging from 50 to 250 mm/year, Petra has been periodically interested by high intensity sudden and concentrated rainfalls, triggering floods along the existing drainage system, with subsequent erosion and seepage phenomena into the subsoil and the following appearance of interstitial pressures.

Besides, the presence of overlapping multi-level caves, on the one hand weakened rocky masses[11], on the other hand caused some collapses on the vaults, due to deterioration and thrusts of pillars and rocky sections that subdivide the various tombs and caves. Progressive bottom-up collapses have thus occurred until the whole side has undergone massive collapses. The collapse of pillars may also occur during seismic events that generate cyclic stresses that are connected with the pre-existing fractures. In brief, the main reasons of structural deterioration to which we can associate the risk of losing some precious monuments in Petra, can be summarized in the following points:

a) Deterioration of the rock and of the discontinuity network.
b) Artificial and natural drainage network and triggering of erosion phenomena, floods and water infiltration into the subsoil.
c) Deterioration and structural collapse of vaults and cave pillars.
d) Medium-high magnitude earthquakes and related damages.
e) Excessive removal of the rock and heterogeneous weights distribution into complex cave systems.

Examples of whole slopes collapse with serious damages on monuments are quite numerous and could increase over time above all in absence of interventions for their protection and static recovery. The Urn Tomb has been identified as one of the most important monuments at risk. Actually, intense erosions together with initial collapses of rock and physical-chemical deterioration of the surface layers could soon determine the loss of the monuments (Fig. 8). Several solutions to limit and stop gravitational and erosive processes in Petra, often irreversible, can be adopted but involving high economic charges of which only the international community can make itself responsible in order to apply historical heritage protection policies.

They must start from organic studies as well as from a global plan and according to priorities, they must identify prevention and consolidation actions suitable for the single static configurations. This first phase of study has allowed to identify some important heritage conservation actions starting from a recovery and restoration intervention of the ancient water drainage network as well as the regulation of the local drainage system. The rocky pillars of caves need to be restored and reinforced. Then, work in order to reinforce the vaults of the caves can be necessary.

Finally, in some sites, it is necessary to protect surfaces exposed to meteoric agents and fix fractures that cause the collapse of vaults and pillars.

Dougga: Dougga (or Thugga) is one of the most important archaeological sites in Tunisia protected by UNESCO as a World Heritage site since 1997. It is situated 100 kilometres south-west from Tunis on the slopes of the Tebersouk Mountains. It was first inhabited by Numides, whose traces are in Massinissa Mausoleum (138 BC), then by Romans until II-IV century AD and finally by Byzantines who left their traces until 533 AD when the final decline began and the consequent abandonment by the inhabitants occurred probably because of a series of natural disasters that happened repeatedly and progressively destroyed it.

It is one of the best preserved archaeological settlements in Tunisia and is home to numerous and important monuments including the Amphitheatre built in 168 AD, the Capitol, the Wind Square with a mosaic depicting the wind rose, the Forum, the Temple of the Concord and the Thermae of Cyclops that cover an area of about 25 hectares.

The area of Dougga falls along the northern border of the African plate in the magrebide chain composed of basal sediments from Carboniferous-Permian followed by clastic and carbonate materials with local evaporate sediments from Triassic and Jurassic up to clastic soils of Pliocene-Quaternary that covered the perimediterranean depressions bordering the continent.

On the whole, the substratum of this settlement is represented of a calcareous and calcareous-dolomite basement S-SW oriented. It appears on the north side near Saturn's Temple, Dolmens and the Amphitheatre followed by an alternation of clays and limestones rather deformed, altered on surface and plastic in presence of water (Fig. 9).

Dougga is located in the geographic area of the High Tell within an hilly area built on a relief with steep slopes on the northern side and gentle ones on the southern side. Because of the steepness of the slope, the ancient town was developed along morphological steps, even artificial, supported by retaining walls with vertical elements separated by septa composed of thick horizontal segments, resistant structures and at the same time able to be deformed as regards to slight thrusts. This terraced configuration caused a series of changes and unbalances within the distribution of loads in depth especially in the medium-low part of the town where incoherent clay gravelled soils prevail (Fig. 10).

Consequently, supporting structures have remained almost intact in some parts, while others are visibly deformed or have even collapsed over time along with the buildings behind. These issues can be found above all along the slope that develops approximately between Venus House and Shamrock House where deformations into the clayey soil are evident.

In the same area, characterized by signs of the landslide instability, buildings are based partly on the unaltered clayey soil and partly on a detritic cover composed of calcareous elements even of great volume with a clayey matrix that could be plastic at times. Therefore, the geomorphological configuration of the slope is characterised by the presence of various evolutionary and morphogenetic elements among which there is an area characterised by deformations of a plastic type that appear with a slow sliding, locally accentuated because of the plasticization of the clayey components.

It deals with a slow planar shift landslide whose border has been identified mapping the place and getting images from the space. The collected data, implemented with SIMONA system, made it possible to delimit the unstable area in which Dougga repeatedly underwent deformations and displacements even if inhabitants tried to find a remedy by building catchwaters channels for rainwater (some of which are still visible today) and retaining walls (Fig. 11). On the opposite side, the steep calcareous slopes are concerned with active rockfalls.

Since the main causes of landslide triggering are not only due to the water infiltrations or the poor geotechnical characteristics of the soil and the geo-structural configuration of the slope, but also to the seismicity, a hydraulic renewal intervention of the area is necessary through the realisation of a functional system of collection, drainage and removal of the water. Then, the reinforcement of the monumental structures is also necessary in order to embank movements of the soils in action and save Dougga from its progressive deterioration and from the risks caused by natural disasters as above all, landslides and earthquakes.

Delphi: Delphi, the major cult site for the ancient Greek and the Hellenic world, is located along the slope of Mount Parnassus (2457 metres) north of the Corinthian Gulf at 570 metres above sea level. It was brought to light by studies and excavations in 1892 and is now a UNESCO site. The sanctuary hosted the oracle of Apollo (the Delphi oracle) and it consisted of terraces on a steep slope that converged into a deep fluvial incision. This site gradually expanded uphill where Greek cities erected some buildings containing votive offerings called "thesauroi". The site overlooks the Pleistos valley and is dominated by steep and tall rocks called "Phedriades" that form the springs of Castalia from which a holy spring originates (Fig. 12).

There are various and important monuments including the Temple of Apollo with the Stadium, the Athena's Sanctuary and several votive shrines as the Athenian Treasury and a big theatre all connected by the Holy Street. At present, Hellenic buildings coexist with roman buildings and early Christian church structures. Moreover, the area was surrounded by a protective wall about 190 metres long and about 135 metres wide interrupted by nine front doors.

This settlement was frequently affected by earthquakes and landslides of various typologies and severity that even in the Hellenistic epoch, damaged monumental structures. A documented earthquake occurred in 373 BC and it triggered a large landslide that damaged the temple of Apollo. In 480 BC a series of rockfalls from the reliefs above the site damaged the temple of Athena Pronaia that for this reason has been moved to safer places.

As it is clear from the field studies, the images and the cartographic database of the environmental monitoring system SIMONA, the area of Delphi develops along the tectonic alignment characterised by various active direct faults that border the slopes of Mount Parnassus and mark the collapse of the entire slope towards the Pleistos river below[14,16]. They are transversely cut by a reverse fault towards NNE-SSW that drains rainfall into the hydro geological basin that separates the massif of Mount Parnassus from that of Mount Kiona supplying even Castalia Spring, a karstic overflow spring considered sacred by the ancient Greeks.

The archaeological site occupies a large morphological step. It is a steep step both uphill and downhill. It has got at the base white and grey thin layers limestones with a microcrystalline structure and bauxite inclusions alternated with thin limestones and reddish schists with chert curbs and nodules. Through a tectonic contact, this basement is covered with a carbonate succession of platform that characterizes the entire archaeological area.

The following tectonic phases caused intense folding of the plastic components as well as a high fracture of the calcareous layers affected also by common phenomena of karstification and physical-chemical dissolution that created fans and detritic nappes at the foot of the slope, even in the archaeological area of Delphi[23].

The ancient structures are partly on the bedrock and partly on Holocene heterogeneous detritic deposits characterized by a mixture of reddish sandy-clayey silts with coarse gravels. The complex static configuration of Delphi points out elements of instability that are very common on the territory characterised by different landslide typologies and dynamics.

Figure 14: Historical image representing the half-destroyed village upstream of Cattaro because of an earthquake occurred on May 29, 1979. On the right, rockfalls triggered by the earthquake are also showed

Rockfalls associated with widespread erosion and detritic slips occur along the border of the calcareous wall situated on the top of the site. These phenomena produce toppling and rolling of calcareous blocks as well as recurrent debris flow in consequence of intensifying pluviometric events.

Figure 15: Example of destructive effects occurred on the ancient historical centre of Bar during the 29 May 1979 earthquake

Different phenomena have been identified on the slope above the ancient and recent settlements of Delphi where landslides occur between the archaeological area and the bed of the river Pleistos through the slip of detritic covers and clayey masses. These landslides belong to the reverse fault that transversely cuts the slope as it is evident from the pictures and database of SIMONA.

This dangerous instability presents both short and long term effects because deformations of the soil have caused thrusts and translations on buildings and handmade since their construction centuries ago whereas the risk of a slip in mass in case of concomitant causes of seismic and hydrogeological origin remains. Moreover, from the analysis of the excavations, it seems that such a phenomenon occurred in the middle Ages in the post Byzantine epoch.

The protection of the site is urgent and the first step requires the protection of the soil from the erosion and the regulation of the superficial waters. It is also necessary to create rockfall defence structures and supporting structures for the most unstable parts of the slope.

Coastal centres in Montenegro: Montenegro coastal area is one of the most charming in eastern Adriatic with centres, referred to Paleolithic, Neolithic and afterwards to Illyres, Greeks, Romans, Byzantines and Turks, characterized by great architectural and monumental relevance, such as Cattaro, Perast, Budva, Bar and Ulcinj, declared World Heritage by UNESCO.

The area is within a very complex territory from the point of view of the geomorphological and seismic dynamics. It is located in the middle-southern dinaric region along the eastern border of the Adriatic plate where there is an accentuated seismic shaking with medium-high magnitude values (Fig.13). Moreover, the prevailing geological successions are very tectoniced and with low resistance values so that the activation of landslides is frequent and dangerous. More precisely, the coastal area of Montenegro belongs to the perimediterranean zone that marks the tectonic limit between the Euro-Asian plate and the African one, where a strong seismicity is concentrated with a high frequency of events with Ms>4. For example, in the southern Dinarides between 1823 and 1979, 10 seismic events occurred with a magnitude comprised between 5,9 and 6,7. They caused damages more or less serious to the inhabited settlements (Fig. 14).

These events are associated with the stratigraphic-structural coastal units in Montenegro, where it is possible to find calcareous-marly-clayey tectonic sequences at the base, covered up by Pliocene-Quaternary sediments mainly of continental and marine conglomerate-sandy type. Instead, the highest parts of the reliefs are composed of dolomitic-calcareous sediments of platform that are definitely fractured and karstified[22].

One of the most destructive events that hit the entire coastal strip was the earthquake dating back to April 15, 1979 and the following on the 29 May 1979 which occurred with an intensity of Ms=6,7 and the epicentre along the Adriatic coast between Budva and Ulcinj killing 101 people and about 1800 injured. Montenegro was affected by plenty of damages. Actually, 250 inhabited settlements were damaged including all the cities overlooking the Adriatic[4]. Monuments, cultural goods, infrastructures and historical centres suffered damages sometimes irreversible as well as serious losses that have been partly recovered, thanks to international aids and UNESCO. During this seismic event, in many areas rotational landslides and rockfalls were occurred, above all close to Cattaro and Perast sites, where traces of landslides are still more evident (Fig. 15).

Cattaro and Budva's historical centres are based on a floodplain characterized by melted recent deposits with low diagenetic and saturated level that increased the structural damages due to thickening or liquefaction of the base. On the contrary, Bar's historical centre shows a different situation. Its fortress rests on a rocky spur that is seriously fractured and where amplification and seismic resonance phenomena occurred bringing devastating effects on ancient monuments sometimes reduced into shapeless blocks rolled down the slope. Even the promontory that hosts the ancient fortress of Ulcinj, composed of yellowish layered calcarenites with conglomerate levels, was affected by strong amplifications with consequent serious effects on the statics of the medieval structures.

Most of these settlements have been recovered and rebuilt so that today they are important cultural and environmental touristic centres. Structural recovery of houses and monuments has reduced the seismic vulnerability of urban centres whose preservation requires consolidation and static recovery works for the slopes.

Conclusion

The dynamics of the slopes within the Mediterranean basin is quite active when in case of specific pluviometric and geological-structural conditions. The former are characterised by very intense pluviometric events that occur in relatively short time spans and they are typical of desert and dry-temperate climates. The latter mainly relate to clayey soils affected by compressive and distensive stresses that have slightly altered the structure and the consistency of masses often hit by evident deformations and tectonic displacements. In such environments erosions and landslides as well as deep gravitational movements of entire slopes are frequent.

The effects on the soil that have been affected by a number of seismic events show that many mass movements were triggered or reactivated in conjunction with strong earthquakes that characterise broad segments of the Mediterranean area. These phenomena influenced the development of civilizations and the preservation of monumental and artistic heritage. Therefore, according to past landslides and earthquakes which affected entire civilizations, the hypothesis is well founded, because the natural disasters are coming to a social and economic standstill and suffering structural damages at times relevant and unrecoverable [5,27].

All the studies carried out on different Mediterranean historical and archaeological centres have pointed out that on one hand structural deterioration phenomena in progress and on the other hand the necessity of intervening with appropriate programmes in order to reduce the vulnerability of many important goods, patrimony of the human being and testimony of his culture.

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